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Oxidants and Asthmatics in Los Angeles
A Benefits Analysis--Executive Summary

Energy and Resource Consultants, Inc.
Boulder, CO

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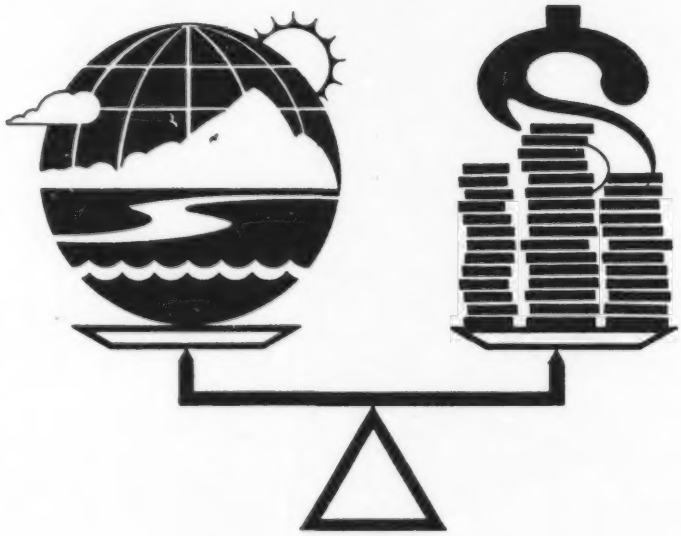

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16. Abstract (Limit: 200 words): Examines changes in behavior, expenditures, and willingness to pay (WTP) as related to asthma severity and air pollution. Summarizes results of both phases of research. Phase I examined information for a panel of 82 asthmatics, representing a population expected to be sensitive to ambient oxidant levels. The study focuses on measuring mitigating behavior and its effect upon epidemiology and economic studies, and on the importance in morbidity valuation studies of using a WTP benefit measure rather than a cost of illness (COI) measure based only on work loss and medical expenditures. The Phase I initial results are reported in EPA-230-07-85-010 (PB 85 228997) Oxidants and Asthmatics in Los Angeles: A Benefits Analysis. Additional analysis (and some minor corrections) are reported in EPA Addendum to Oxidants and Asthmatics in Los Angeles (also available through NTIS)

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EXECUTIVE SUMMARY

OXIDANTS AND ASTHMATICS IN LOS ANGELES:

A BENEFITS ANALYSIS

Robert D. Rowe
Lauraine G. Chestnut
Energy and Resource Consultants, Inc.
P.O. Drawer O
Boulder, CO 80306
(303) 449-5515

Prepared for:

Ann Fisher
Office of Policy Analysis
U.S. Environmental Protection Agency
and
Sylvia Champomier
Research Division
California Air Resources Board

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1.0 INTRODUCTION AND OBJECTIVES

This study examines changes in behavior, expenditures, and willingness to pay as related to changes in air pollution and to changes in asthma symptoms. It is based upon information for a panel of 82 asthmatics in Glendora, California, gathered in the fall of 1983 and analyzed in 1984 and 1985. The panel of asthmatics represents individuals of a population expected to be sensitive to ambient oxidant levels. It was conducted in cooperation with the U.S. EPA, the California Air Resources Board, and the UCLA Schools of Medicine and Public Health. The UCLA study included a year long epidemiological analysis relating air pollutants and other agents to asthma symptoms (Gong et al. 1986). This summary covers the findings of the economics study conducted by Energy and Resource Consultants, Inc. (ERC) as reported in Rowe and Chestnut (1985, 1986).

The objectives of this study were:

- To examine the potential effect of mitigating behavior on epidemiological estimates of the relationship between oxidants and asthma symptoms,

- To estimate conceptually correct willingness to pay (WTP) benefit measures for changes in asthma severity and compare these WTP measures to the cost of illness (COI) measures that are most frequently used to value changes in adverse health symptoms, and

- To provide economic data for use in calculating benefit estimates for a sensitive population, in this case asthmatics, for changes in oxidant levels.

In addition, refinements to the contingent valuation benefit estimation method were developed and implemented.

The first two objectives of this study were meant to address two limitations that often occur in economic studies aimed at valuing changes in health status

due to changes in environmental pollutants. Typically, economic studies use epidemiology results to estimate changes in health status variables as a function of changes in environmental quality. Such health status variables often include changes in work loss and specific health effect measures. Next, values are assigned to work loss, and medical expenditures are estimated for the change in health status. The combination of work loss and medical expenditures are referred to as the COI measure of damages. This economic valuation approach may tend to understate the value of health impacts of environmental pollutants for at least two reasons.

- o If individuals perceive potential risks and undertake expenditures and behavioral adjustments to avoid or mitigate exposure to environmental pollutants, then benefits estimates based on observed epidemiological relationships between pollutants and health status may be biased toward zero unless such behavior adjustments are accounted for. Further, the estimated epidemiological relationships may show a pollutant threshold level at which statistically significant health and welfare effects are observable that is higher than the true threshold that would be estimated if mitigating behavior were considered.

- o COI measures of damage for changes in health status may understate the value of changes in health status. For example, any discomfort experienced, or changes in activities undertaken to prevent or treat illness, may be valued in addition to work loss and medical costs incurred. To date, few studies have attempted to quantify the importance of discomfort and activity effects associated with changes in health status.

2.0 AN ECONOMIC MODEL OF VALUE AND MITIGATING BEHAVIOR

The economic analysis is based upon a health production function model derived from those by Harrington and Portney (Forthcoming) and Gerking et al. (1983). The model is used to illustrate the level of defensive expenditures and activities the individual will choose to undertake, how epidemiological

analyses can be affected when defensive expenditues are ignored, and the components of willingness to pay. The primary conclusions of the model are:

1. Individuals will engage in defensive efforts to minimize adverse health effects to the point where marginal benefits equal marginal costs in terms of time and money spent for defensive efforts.

2. An individual's WTP to reduce risks of adverse health effects associated with exposures to air pollution is expected to include values related to the following damage categories.

    i. Medical expenditures for the prevention and treatment of illness.

    ii. Foregone income due to time off work, and lower wages or lower productivity at work because of the prevention and treatment of illness.

    iii. Disutility of reduced ability to participate in desired leisure activities, household chores, child care, choice of where to live and recreate, and other activities because of the prevention and treatment of illness.

    iv. Disutility of discomfort due to illness.

3. COI estimates, based only upon medical costs and work loss will probably understate WTP to reduce health impacts by missing the value of discomfort and by ignoring the value of preventive expenditures and behavior changes to prevent and respond to illness. A willingness to pay measure incorporates all of the relevant effects.

3.0 SURVEY DESIGN

Two sets of survey instruments were used: (1) The UCLA instruments, used for the epidemiology analysis; and (2) the ERC daily diary questionnaire, and the ERC general background and WTP questionnaire.

The UCLA Epidemiology Surveys and Analysis

UCLA researchers collected data on over 90 subjects with diagnosed asthma. The data were collected over an eleven month period from January 1983 through November 1983. All of the subjects lived in Glendora, California, a town in the San Gabriel Valley east of Los Angeles, where state and federal standards for ambient ozone and other pollutants are exceeded frequently. At the beginning of the study each participant completed a general questionnaire on medical history, asthma symptoms, household and socioeconomic characteristics and other data.

During the study period, each subject kept a daily record of his or her asthma symptoms. These were measured in three different ways: (1) subjects rated their daytime and nighttime symptoms in several categories on a 1 to 7 severity scale; (2) subjects took twice daily readings of their pulmonary peak flow; and (3) subjects used, as needed, an inhaler that recorded the amount of medication used. Every two weeks the subjects were given more extensive tests and answered questions about any illnesses they may have had or other things that may have affected their asthma during the two week period. Air pollution levels were taken from the South Coast Air Quality Management District Station 60. Weather conditions and the amount of pollens, fungal spores, and potential aeroallergens were measured at the on-site facility. See Gong et al. (1986) for additional details.

The ERC Economic Surveys

The economic surveys were designed to obtain additional information from the UCLA panel without interfering with the UCLA study. Subjects aged 16 and over (the adult group) were asked to complete a diary at home each day for four weeks and to complete the general questionnaire during their last visit to the

UCLA facility. The parents of subjects under sixteen years old were asked to complete the general questionnaire only. Sixty-four of the then current sixty-five adults, and parents of all eighteen of the panelists under sixteen agreed to participate.

Several of the questions referred to "bad asthma days" so as to determine how the subject adjusts his or her activities when his or her asthma is "bad". What is "bad" will be different for every individual. Each subject therefore was asked to pick the highest rating on the seven point UCLA severity scale that he or she would still consider to be a "good asthma day". The respondents had been using the UCLA seven point severity scale to rate their daily asthma for the past 8 to 10 months and were quite familiar with it. The subject then was told that when the questions referred to a "bad asthma day" it meant any day on which he would rate his asthma symptoms higher (worse) than the selected point.

The Daily Diary. During October and November 1983 respondents provided diary information on perceptions and activities. The objectives were to determine if these individuals perceive air pollution as affecting their asthma, determine if their perceptions accuractly correlate with ambient conditions, and examine whether they alter their behavior to reduce or minimize adverse asthma symptoms when they anticipate having a bad day with air pollution as a possible cause.

Six questions were asked each day:

- When the day started, what did you think might affect your asthma during the day?
- When the day started, did you think you might have asthma symptoms that would result in a bad asthma day?
- How did your asthma symptoms affect your work, schoolwork or housework that day?
- How many hours were spent in different activity categories?

- o Did you change your leisure activities to avoid having or worsening asthma symptoms that you would consider to be a bad asthma day?

- o Did you change your sleep activities to avoid having or worsening asthma symptoms that you would consider a bad asthma day?

The General Questionnaire. The general questionnaire identified ways in which asthma affects the respondents' well-being. It provided data for estimating economic measures of changes in well-being associated with changes in the frequency of asthma symptoms that result in a bad asthma day.

The questionnaire consisted of seven sections. The first six addressed asthma effects on medical expenditures, work and school, leisure and chores, and residential choice. Part VII of the questionnaire asked respondents to rank in importance five categories of benefits they might receive if their asthma improved including lower medical expenditures, higher income or productivity, more flexibility about where to live, better chance to participate in leisure activities, and less pain and suffering or discomfort. After the ranking, respondents were asked how much they would be willing to pay in additional taxes each year for a program that would reduce their bad asthma days by one-half. Evaluation of zero bids, the medical cost data, and ranking responses were used to analyze the internal consistency of the individual's WTP responses. The final question was household income. Other socioeconomic variables were available through the UCLA questionnaires.

4.0 RESULTS OF THE DAILY DIARY ANALYSIS

Each of 64 adult respondents completed the diary for an average 27.8 days resulting in a total of 1779 observations (or person-days). Individuals started the diary between October 12 and November 2, 1983, depending upon their schedule of visits to the UCLA Glendora facility. Due to being late in the fall of the year and the unusual amount of rain, there were only 13 days with peak hourly ozone readings in excess of 12 pphm (the federal standard) in Glendora during the study period, although peak hourly readings above 30 pphm

are not uncommon in the summer and early fall in this area. The low pollution levels mean that it may be more difficult to identify mitigating behavior in the diary results.

For analysis purposes, the diary data were analyzed with both the "full sample" of 64 individuals and a "reduced sample" of 32 individuals who checked air pollution as a possible factor aggravating their asthma on one or more days. It was felt that those individuals who never indicated air pollution as a factor were, in their opinion, either not sensitive to air pollution or were not aware of air pollution at the levels experienced during the study period, and could not be expected to alter their behavior in response to changes in their perceptions about air pollution, which was the relationship of interest.

Perceptions About Air Pollution

If respondents accurately perceive air pollution and then act to mitigate any possible adverse effects, this should be important to consider in epidemiology and economic studies.

The respondents checked air pollution as a factor potentially aggravating their asthma on only 292 person-days (16.4 percent of the total). The infrequency of this response could have been the result of the unusually low pollution levels. For those days when air pollution was checked, respondents were more likely to check tension, stress, and anxiety; and animals, plants, and pollens; as potentially aggravating their asthma. This suggests that asthmatics perceive that air pollution is more likely to affect their asthma when other factors are also present or vice versa.

Both ordinary least squares and logit regression analyses (See Table 1 for definition of variables and Table 2 for results of these analyses for the reduced sample) demonstrate that the probability of checking air pollution as a factor possibly aggravating asthma symptoms during the day is significantly related to actual ambient oxidant levels (as well as to total suspended particulate levels, which were highly correlated with oxidant levels). Differences in asthma severity did not influence perceptions about air pollution. The analysis suggests that for a day with a peak hourly O_3

Table 1

Definition of Variables

Name	Definition	Source
AQ1	Maximum hourly ozone reading (pphm)	CARB
AQ2	Daily Average Ozone (pphm)	CARB
A2	Concerned that illness might affect asthma today = 1, 0 otherwise	Diary
A3	Concerned that tension, stress might affect asthma today = 1,0 otherwise	Diary
A4	Concerned that exercise might affect asthma today = 1, 0 otherwise	Diary
A5	Concerned that air pollution might affect asthma today = 1, 0 otherwise	Diary
A6	Concerned that allergies might affect asthma today = 1, 0 otherwise	Diary
A7	Concerned that weather might affect asthma today = 1, 0 otherwise	Diary
A8	Concerned that a bad day yesterday might affect asthma today = 1, 0 otherwise	Diary
EXP4	Expected a bad asthma day with exercise as a concern	Diary
EXP5	Expected a bad asthma day with air pollution as a concern	Diary
EXP6	Expected a bad asthma day with allergies as a concern	Diary
EXP7	Expected a bad asthma day with weather as a concern	Diary
TEMP	Daily temperature (F.) at 1 p.m. at El Monte airport	UCLA
HUMID	Daily relative humidity at 1 p.m. at El Monte airport	UCLA
PRECIP	Daily precipitation (inches) at Glendora West Fire Control	UCLA
AGN1 to AGN10	Ten daily allergen levels (trees, shrubs, molds, etc.)	UCLA
SYMPTOM	Summary of daily asthma symptoms reported by the respondent over the entire UCLA study period; used as an indicator of severity	UCLA
HOA	Daily hours in outdoor active activities	UCLA
WEEKEND	1 if a non-work day for the individual, 0 otherwise	UCLA
SEV	Severity of asthma based upon respondents reported monthly frequency times intensity (reported on UCLA instruments) summed over the calendar year	UCLA
INC	Income	General
AGE	Age	UCLA
SEX	Sex; 0 = male, 1 = female	UCLA

Table 1 (continued)

MEDVHH	Variable medical costs/year paid by the household for this asthmatic (doctors, hospitals, medicines, etc.)	General
RTFM	Respondent's share of total household asthma (0-100%)	General
GDAY	Highest day rating on UCLA scale still considered to be a good day	Diary and General
NBAD	Number of bad days/year - number of days where the day rating is greater than GDAY	UCLA
NBADR	1/2 NBAD = Number of days reduced in WTP scenarios	--
ADULT	Is the respondent an adult (16+ years) 1 = yes, 0 = no	General
TAXBID	WTP response to reduce bad asthma days in half through a tax vehicle	General
NOBS	Number of observatories used in the analysis	--

Note: The prefix D is used to denote deviations from the mean, P to denote percentage of the mean and LN to denote the natural log of the variable.

UCLA = UCLA Survey Instruments
Diary = ERC Daily Diary Survey Instrument
General = ERC General Questionnaire
CARB = California Air Resources Board

Table 2

Results of the OLS and Logit Estimation of the Perceptions Equation for the Reduced Sample*

Dependent Variable = A5 (Respondent felt air pollution might affect asthma that day, mean = .318)

Explanatory Variable	Variable Mean	Logit Coefficients	OLS Coefficients
Constant		-.572 (1.17)	.358 (3.7)
AQ1	8.3	.88 E-1 (5.61)	.18 E-1 (5.8)
SEV	172.4	-.11 E-2 (.83)	-.18 E-3 (.69)
INC	32125	-.34 E-5 (.74)	-.82 E-6 (.77)
AGE	38.5	-.49 E-2 (.83)	-.89 E-3 (.78)
SEX	.52	-.93 (5.48)	-.191 (5.65)
R^2			.086**
F			16.2
Likelihood Ratio Test		76.38	
NOBS	866	866	866

Source: Rove and Chestnut (1985, 1986)
* t-statistics given in parentheses.
**The R^2's reported in Rove and Chestnut (1985) were in error. The multiple R was incorrectly reported. The correct R^2's for previous Table 4.3 are:

Equation:	1	2	3	4
R^2:	.040	.043	.086	.088

level equal to the federal standard of 12 pphm, 41 percent of the males and 28 percent of the females in the reduced sample will observe the air pollution and expect it to affect their asthma. Looking at the "full sample," the percentages who will expect air pollution to affect their asthma are about half the rate for the reduced sample.

Pollution and Daily Schedule

If asthmatics perceive that air pollution might aggravate their asthma, these perceptions may cause them to take averting or responsive actions in terms of altering their daily schedule to minimize adverse symptoms. For example, one might spend less time in active outdoor activities, because pollution levels are typically higher outdoors on high pollution days and exercise can aggravate asthma symptoms. Three sets of models were analyzed to examine this hypothesis.

The first set of models used ordinary least squares (OLS) regressions to relate changes in hours spent in seven activity categories to expectations that a bad asthma day might occur and that air pollution was a potential aggravating factor. To isolate substitution in time spent in different activities as a result of differences in expectations about asthma that might be related to air pollution, these models were estimated for those individuals in the "reduced sample." The results indicate that when these asthmatics expected a bad asthma day with air pollution as a possible factor, they spent less time on chores and both active and inactive leisure, and more work loss occurred. However, the statistical significance of these results was generally weak.

The second set of models considered the potential simultaneity between expectations of a bad asthma day and hours spent in different activities. It was hypothesized that the individual would spend less time in active outdoor activities on days when he or she expected a bad asthma day and was concerned about air pollution. It was also hypothesized that on days when more active outdoor activities were planned, the individual might be more likely to expect a bad asthma day related to air pollution. To the extent that this

simultaneity exists, it could have biased toward zero the OLS coefficients relating changes in activities to expectations about bad asthma days where air pollution was a concern.

To simplify this second analysis, all active outdoor leisure and work hours were aggregated into a single variable for hours in active outdoor activities. Two stage least squares was used to estimate two equations: one for hours in active outdoor activities, and the other for whether or not the individual expected a bad asthma day with concerns about air pollution as a potentially aggravating factor. The results of this estimation suggest that the simultaneity between hours in active outdoor activities and expectations about air pollution effects is not statistically significant for the sample group and time period, although the coeffients on these variables were of the expected signs.

Given the lack of evidence of simultaneity, another OLS model was estimated incorporating the refinements from the simultaneous modeling effort. These results, reported in Table 3, indicate that expectations that air pollution may contribute to a bad asthma day lead to an average 20 percent reduction in active-outdoor activities for individuals in the "reduced sample." Contrary to previous analyses, these results are statistically significant.

In summary, each of the modeling efforts indicated that if respondents who are concerned about air pollution expect a bad asthma day with air pollution as a contributing aggravating factor, they will substitute behavior in a manner that may be expected to reduce adverse asthma symptoms. These changes in behavior are potentially substantial, on the order of a 20 percent reduction in time spent in active outdoor activities. This change in behavior is likely to be a combination of mitigating and responsive actions. It should be noted that during the study period, oxidant levels were generally quite low relative to levels experienced during the mid-summer. Had higher levels of oxidants been experienced during the study period, even larger substitutions in activities might have been observed.

Table 3

Relationship Between Changes in Active Hours Spent Outdoors and Expectations That a Bad Asthma Day May Occur

Dependent Variable = DHOA Variable	Coefficient	t-Ratio
CONSTANT	.222	.27
EXP4	.147	.50
EXP5	-.627	-2.52
EXP6	.579	1.92
EXP7	-.317	-1.41
WEEKEND	1.647	7.15
A2	-.315	-1.31
A3	.303	1.70
A8	-.373	-1.48
PRECIP	.199	.45
TEMP	-.0050	-.44
R^2 = .10,		
F = 6.53		

Source: Rove and Chestnut (1986)

5.0 RESULTS OF THE GENERAL QUESTIONNAIRE ANALYSIS

Medical Expenditures

Expenditure data were collected on medical supplies, equipment, and special treatment programs. These data were separated into fixed and variable costs and adjusted by the number of asthmatics in the household and the amount paid by insurance. Information on doctor and hospital visits was obtained from the respondents and from UCLA. Sample averages are reported in Table 4.

Estimated variable medical costs paid by the household and attributed to the respondent, including medications, treatments, doctors, and hospitals, were regressed against asthma severity (SEV) and selected socioeconomic variables (Table 5). Significant in the regression results is that the elasticity of variable medical costs with respect to severity is just less than one, indicating that variable costs increase just less than proportionally to severity. A variable for whether or not the respondent had insurance was never significant when included and had minimal effect on the estimates of other coefficients.

Effects of Asthma on Work, School, Non-Paid Chores, and Leisure

The survey results indicate that for the sample population, more severe asthma is likely to affect short-term and long-term earnings potential. Of the 47 respondents employed full or part-time, 20 felt their choice of job was affected by their asthma. Twelve respondents felt their asthma affected their income. These respondents had, on average, higher asthma severity than the rest of the sample.

Turning to students, nearly two of every three felt their asthma affected their performance at school, particularly their extracurricular activities (63%) and their grades (40%). (Recall that there are only 16 students in the sample.)

Eighty percent of the adult asthmatics felt that their asthma affected their ability to perform chores that they routinely do, but do not get paid for.

Table 4

Average Medical Costs per Year for 82 Asthmatics in Glendora, California

	Household Total	For This Asthmatic
Total Fixed Cost Expenses	$713	$573
Total Variable Expenses/Year	528	435
Household Paid Fixed Cost Expenses	619	486
Household Paid Variable Cost Expenses/Year	268	208
Insurance Paid Fixed Cost Expenses	94	87
Insurance Paid Variable Cost Expenses/Year	260	227

Fixed cost expenses refer to one-time goods such as Intermittent Positive Pressure Breathing Machines.

Variable costs refer to expenses repeatedly incurred such as for medicines or doctors visits.

Insurance includes government programs.

Table 5

Variable Medical Costs as a Function of Asthma Severity

Dependent Variable: Log of variable medical costs paid by the household; LN (MEDVHH)

Explanatory Variable	Coefficient	t-ratio
Constant	-1.13	-.49
LN (SEV)	.92	2.40
LN (INC)	-.105	-.47
LN (RFTM)	.45	1.06
ADULT	-.51	-1.33
SEX	.90	2.86
F	4.73	
R^2	.24	
NOBS	82	

Sample: Full General Questionnaire Sample

See Table 1 for variable definitions.

Source: Rowe and Chestnut (1985)

Nineteen percent (10 respondents) hired help on a regular basis to perform chores that they would perform themselves if their asthma were less severe. These individuals spent an average $1,478 per year for these services, and had significantly higher average asthma severity relative to the remainder of the sample. Analysis of costs of chores hired and asthma severity for these individuals indicates that a 10 percent increase in severity results in an 8.8 percent increase in expenditures for chores hired out in part due to asthma.

Asthma affects leisure activities for nearly 75 percent of the respondents. The respondents indicated that most often they change their activities or spend less time in leisure activities while occasionally doing the same activities at a different time of day.

Rankings

Respondents ranked, in descending order of importance, five benefits they might receive from reduced asthma. This question was a final step in preparing respondents for the total willingness to pay question and, in combination with estimated medical costs, provided a validation check on the WTP responses. The rankings are summarized in Table 6a. Assigning values of one when a category is ranked first and five when a category is ranked fifth, and six if the category is not ranked, yields the overall mean ranking.

Table 6b presents t-test results for the hypothesis that the mean scores are identical. The t-tests reject the hypothesis that the mean scores are identical except for medical costs and work loss. Discomfort and asthma effects on activities were clearly ranked above cost of illness measures of medical costs and work loss, which were ranked very closely to each other. The low ranking for the residential flexibility should be cautiously interpreted because it is based upon the responses of a group of asthmatics who live in a very high air pollution area. They have not moved in order to reduce their exposure to air pollution, which may aggravate their asthma, and they may not be representative of other asthmatics in this regard.

A discriminant analysis was also used to examine the relationships between the rankings and the characteristics of the respondents. The results indicate

Table 6

Results of the Ranking

a. Rankings

Category	Overall Rank	Mean Score	SE of the Mean	Times Ranked 1st	2nd	3rd	4th	5th	Times not Ranked (=6)
Discomfort	1	2.16	.16	40	19	11	1	4	7
Activities Effects	2	2.89	.18	22	20	12	13	3	12
Medical Costs	3 tie	3.63	.20	12	14	19	8	5	24
Work Loss	3 tie	3.79	.20	7	20	14	11	2	28
Residential Choice	5	4.88	.15	1	6	9	10	16	40

b. t-ratios* on Pairwise Comparisons of Average Scores

	Discomfort	Activities	Med. Costs	Work Loss
Discomfort	---			
Activities	3.0	---		
Medical Costs	5.7	2.7	---	
Work Loss	6.4	4.5	.6	---
Residential Choice	12.4	8.5	5.0	4.4

* t-ratio of hypothesis that the mean rankings are equal.
Source: Rowe and Chestnut (1985)

that as age, family size, and number of bad asthma days increased, asthmatics were more likely to rank medical costs or work loss as the most important benefit of reduced asthma. Higher income, being an adult (versus child), and a greater share of total household asthma severity led to increased likelihood of ranking a lifestyle category first.

The ranking results play an important role in subsequent analyses. In these analyses it was assumed that in ranking the importance of each benefit, the respondents considered the net effects of their asthma symptoms after selecting a level of medical treatment. Based on this assumption, it was presumed that willingness to pay for each of the benefits would follow the same order as the rankings. This means, for example, that an individual who is able to fully mitigate adverse effects of asthma with medication would be expected to rank reductions in medical expenditures as the most important benefit of an improvement in asthma and would rank the other benefits as unimportant.

Tax Bid Analysis

The following contingent valuation question was asked: "If federal, state or local governments set up programs that could reduce pollens, dusts, air pollutants, and other factors throughout this area that might reduce your (and your household's) bad asthma days by half, but would cost you increased tax dollars, what would be the maximum increase in taxes each year that you and your household would be willing to pay and still support such a program?"

A payment card with alternative dollar amounts accompanied the question. The question appeared generally to be well received with 69 non-zero responses, 12 zero responses and one refusal. Upon detailed evaluation of the responses (discussed in more detail below), some zero observations were retained and a few non-zero bids deleted, resulting in a mean bid for 65 observations, called the tax bid sample, of $401 per year with a standard error of the mean of $85. This estimate is for an average number of bad asthma days reduced of 37 per year (50% of the average number of bad days). The mean estimated variable medical costs paid by the household for this group of respondents was $272.00 with a standard error of the mean equal to $27.62.

Models were derived from consumer utility maximization that related changes in consumer's surplus, measured by the tax bid, to changes in asthma severity. Table 7 presents estimation results for one of the more simplistic, but statistically most significant, models. The model suggests that WTP increases at about one-half the rate of the number of bad asthma days reduced and increases almost linearly with the level of asthma severity (on the 1 to 7 scale) that was viewed by the respondent as the highest severity that is still a good asthma day. Predicted WTP values for alternative frequency and intensity of bad asthma days using the results of Table 7 are reported in Table 8.

Alternative tax bid specifications considered included variables representing the number of bad asthma days at each intensity level from level 2, days with very mild symptoms, to level 7, days with very severe symptoms. While the coefficients were statistically significant on many of the variables representing bad asthma days at each intensity level, the size and significance of these coefficients were not stable across small changes in the regression specifications. It was presumed this was the result of multicollinearity across these variables.

WTP Response Consistency Checks

A major issue in contingent valuation (CV) studies has been the credibility of the values received through hypothetical questions (Cummings et al., 1984). This survey instrument was designed specifically to examine the plausibility of the CV responses by examining zero and large bids and by comparing the tax bid, medical costs, rankings and other responses. Of the 82 respondents, one refused to respond to the tax bid question and one gave a bid exceeding his stated income. These responses were deleted. Twelve zero responses were given. Based upon a typical zero bid follow-up question eleven bids would have been deleted, but subsequent analysis indicated that five of these bids were probably valid because the individual's asthma condition was such that he or she had zero or one bad day in the last year and very low medical costs. Therefore, reducing bad asthma days by half could appropriately be valued at zero. The remaining seven zero bids were by respondents with at least $150

Table 7

Tax Bid Regression Model

Dependent Variable = LN (TAXBID)

Sample = Tax Bid Sample

Variable	Constant	LN (NBADR)	LN (GDAY)	AGE	SEX	ADULT
Coefficient	4.28	.552	1.08	-.683	-.47	.77
t-ratio	(2.78)	(4.26)	(1.61)	(-1.21)	(-1.09)	(.98)

NOBS = 65 F Statistic = 5.26

R^2 = .308 $\bar{R}^2$ = .250

* Source: Model version 2 Table 10a (revised Table 4.15a) Rowe and Chestnut (1986)

Table 8

Predicted WTP Values ($'s)

Highest Asthma Severity Considered by Respondent to be a Good Day (GDAY)	Number of Bad Days Reduced			
	1	5	15	50
1 (no symptoms)	$ 9	$22	$ 40	$ 79
2 (very mild symptoms)	19	47	86	166
3 (mild symptoms)	30	72	133	258
4 (moderate symptoms)	41	99	181	353

Source: Table 10 (revised Table 4.15b), Rowe and Chestnut (1986) Value predicted for male adults at the mean age.

per year in variable medical costs, 18 or more bad asthma days and who gave a rejection response to the zero bid follow-up questions. These were deleted from further analysis. Four non-zero bids were also deleted from the tax bid sample because for these individuals NBAD equalled zero, while the bid exceeded $100 per year. For these individuals it was presumed that the NBAD estimates, which were extrapolated from six months of data, may have been in error, especially if their asthma symptoms were seasonal. In this case the bids may be valid, but a possible significant error in the NBAD estimate could bias the regression results.

The responses of sixty-eight respondents who gave non-zero bids less than their income were analyzed using the following consistency check. It was assumed that a 50 percent reduction in bad asthma days would yield a 46 percent reduction in variable medical costs (.92 from Table 5 times 50 percent reduction in asthma severity). WTP should therefore exceed .46 of the individual's variable medical costs. Further, if changes in medical costs are ranked third, for example, total WTP should exceed .46 of variable medical costs by at least a factor of three, if changes in each of the above ranked categories are valued the same or more highly than changes in medical costs. If changes in medical costs are ranked fifth then total WTP should exceed .46 of variable medical costs by a factor of five or more and so forth.

A limitation of the consistency check analysis is that while the individuals may have attempted to give accurate and reasonable estimates for their medical costs and underlying values for changes in asthma, measurement error may result in failure of the consistency check.

Of the 68 individuals with responses analyzed with the consistency check, 37 provided medical cost, tax bids and rankings that were consistent with the above assumptions, and another 16 were consistent using a reduction in medical costs of 25 percent or allowing a 33 percent measurement error in either the tax bid or medical cost estimates.

A second important limitation in the consistency check is that the WTP bids are based upon a 50 percent change in bad asthma days, while the estimated reduction in medical costs is based upon a 50 percent change in severity

measured as the sum of monthly frequency times the intensity of asthma symptoms. For an individual with a large number of bad asthma days, a 50 percent reduction in bad asthma days and in overall asthma severity may be quite similar. The correlation between 50 percent changes in these measures is likely to lessen as the number of bad asthma days decreases, which was supported with the sample data. This is another reason for using the alternative of 25 percent of medical costs in a second application of the consistency check. This is viewed as a weakness of the design of the application, rather than the general design of the consistency check procedure.

Overall, the bid evaluation and consistency check procedure indicate the tax bids are quite reasonable once obvious protest bids are eliminated. Of the 73 bids not easily identified as protests (82 less 1 refused, 1 bid exceeding income and 7 protest zeros) 5 were acceptable zeros, 37 passed the consistency check using .46 of the variable medical costs and 16 passed the consistency check using .25 of variable medical cost. Therefore 79 percent of the non-protest responses appear to be quite accurate in terms of their consistency with other information.

Comparing COI and WTP Economic Measures of Health Damage

Economic analyses of health damage often rely upon cost of illness measures (COI) of damage, even though economic theory suggests that these measures are likely to understate conceptually correct WTP value measures. In this section we briefly address the ratio of WTP to COI measures from the perspective of the affected individual and the perspective of society based upon evidence in this study.

The rankings provide the first simple evidence that WTP measures exceed COI measures for the affected individual. If changes in discomfort and leisure activity effects from changes in asthma are both ranked, and therefore valued, more highly than changes in medical costs; and changes in medical costs and work loss are ranked, and therefore valued, approximately equally, then the total WTP (the aggregate value of all damage categories) can be expected to be at least twice COI.

An alternative approach, again from the perspective of the affected individual, is to compare the total WTP tax bid for a 50 percent reduction in bad asthma days to estimated changes in medical costs for a 50 percent reduction in bad asthma days and, following the rankings, make the assumption that work loss equals medical costs for a change in asthma. This leads to a WTP/COI ratio of 1.61.* Other approaches to measuring the WTP/COI ratio suggest that the ratio may be as high as 3.7.

Society incurs costs and may hold values for reductions in morbidity incidences beyond those costs and benefits incurred by the individual. Society directly incurs the full medical costs including those paid by insurance or government programs, while the individual typically incurs less than the full medical costs associated with his illness. Further, society directly incurs lost work productivity when an individual is away from work whereas, due to paid sick leave, the individual may perceive a smaller personal loss. Others in society may hold values related to reduced sickness for those who are affected. This is reflected in the research of Needleman (1976), where WTP by others to prevent an individual's death increased total WTP by 25 to 100 percent.

To obtain an estimate of the WTP/COI ratio from a social perspective, the individual WTP and COI values were escalated by estimated social costs and benefits. On a sample wide basis, households directly paid about one half of variable medical costs while insurance or other programs paid the rest. Therefore the total social medical cost component of WTP and COI is approximately double that of the individual. This survey provides no information to gauge the social versus individual costs related to work loss. Therefore, for the sake of analysis and following the medical cost doubling, we assume total social work loss costs are double the individual's perceived work loss costs. The estimated social COI measure is thus estimated to be roughly double the individual's COI measure. Social WTP also can be expected

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* The estimated change in medical costs for a 50 percent change in bad asthma days equals .92 (percent change in asthma) x $272 (average variable medical costs), or $125. Assuming the workloss change equals the change medical costs (based upon the rankings), COI=$250. WPT/COI=$401/$250=1.61.

to exceed individual WTP. The estimated WTP/COI ratio for society is dependent upon the assumptions about willingness to pay by others to reduce an individual's asthma, which we call Z. Using the above assumption on socially incurred medical costs and work loss and assuming Z equals zero, the WTP/COI ratio ranges from 1.31 to 2.35. Assuming Z equals 50 percent of the individual's WTP, the social WTP/COI ratio increases to between 1.55 and 2.6.

The calculation of WTP/COI ratios undertaken here must be interpreted as suggestive due to measurement error and the assumptions used. With these caveats in mind, the analysis suggests that the WTP/COI ratio for asthma, as we have defined COI measures, are best estimated to be in the range of 1.6 to 2.3, with 2.0 as the best point estimate using the perspective of an individual. Using the perspective of society, the estimated range is 1.3 to 2.0, with 1.5 as the best point estimate. If full medical costs or work loss costs are not included in a COI measure, which is frequently the case due to data limitations, a COI measure may be capturing an even smaller portion of total WTP.

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